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OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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FRONTISPIECE

Very sincerely yours
Percival Lowell.

PERCIVAL LOWELL

Born March 13, 1855; Died November 12, 1916.

Journal of the Royal Astronomical Society of Canada, 1916

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OF THE
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VOL. XI. JANUARY, 1917. No. 1

PERCIVAL LOWELL

BY FRANK W. VERY

ASTRONOMY has suffered a severe loss by the sudden death of the distinguished American astronomer, Percival Lowell, which occurred at Flagstaff, Arizona, on Sunday, November 12, 1916. To those who have had the privilege of listening to Dr. Lowell's lucid expositions of those great astronomical discoveries in which he had a part, the news will come with a sense of keen personal loss. He always took his audiences with him into an inmost intimacy, showed his hearers science in the making, gave a human interest to everything he touched, and by the brilliancy of his faultless diction and his keen but kindly wit, fairly took them by storm.

The clever *bon mots* of a popular lecturer will not always stand the severe scrutiny of a drier and more rigid scientific criticism, but if anyone supposes that Dr. Lowell was a mere maker of happy phrases, he has missed the real genius of the man. As a student at Harvard University, a notable future as a mathematician was foretold for him by his teacher, Benjamin Peirce. This prediction was easily fulfilled. Such papers as the

"Memoir on a Trans-Neptunian Planet" bear witness to long years of industrious investigation in the difficult study of celestial mechanics, and though the actual detection of the body, or bodies (for there is some reason to suspect that there are two of them) did not reward the diligent search by Dr. Lowell and his assistants, there can be no doubt of the reality of the gravitational disturbance made known by the mathematical analysis.

Equally fertile in results requiring the highest sort of mathematical ability in their making, was the demonstration that Saturn has "confocal layers rotating faster within," founded upon the extraordinarily difficult observation, by Dr. Lowell and Mr. E. C. Slipher at Flagstaff, of excessively fine and delicate, dark dividing lines in Saturn's rings, whose fixed positions were found to be attributable to the perturbations of Mimas and Enceladus, but with minute variations which could only be explained on the hypothesis of a yielding of the plastic interior of the planet, and a more rapid rotation of the inmost nucleus with resulting larger oblateness than that of the outer surface.

These achievements place Dr. Lowell's name high on the lists of those who have wrested secrets from nature by severe labor of mathematical and intellectual thought. But his chief fame will still be, that, even more than Schiaparelli, who first discovered the Martian "canals," Lowell was the man who made the map of Mars, enriching it with a great number of delicate markings, and evolving from their patient and assiduous study in all their complex variations, a rational theory of their meaning, which challenges our admiration. And although this theory of the origin of the lines in vegetation, irrigated and made possible by a complicated system of engineering works, has taxed the credulity of some less highly imaginative people, no one can deny its possibility, and no one has ever attempted to suggest a more plausible explanation. It will go down in the history of science as one of the best examples of the exercise of the "scientific imagination."

Dr. Lowell was born in Boston, Massachusetts, March 13, 1855. His father, Augustus Lowell, was much interested in education,

and was for a long time a trustee of the unique "Lowell Institute," founded in Boston in 1836, by a kinsman, John Lowell, Jr. Augustus Lowell was also prominent in the foundation and maintenance of the Massachusetts Institute of Technology, where his son, Percival, was afterwards for fourteen years, non-resident Professor of Astronomy. His mother was Katherine Bigelow (Lawrence) Lowell, daughter of Abbott Lawrence, who was Minister Plenipotentiary from the United States to Great Britain in 1851; and he was also related to the poet, James Russell Lowell, who later held the same position. On both sides, Dr. Lowell came from distinguished ancestry. He was very happily married to Constance (Keith) Lowell, but leaves no descendants.

The cities of Lawrence and Lowell on the Merrimac River, in Massachusetts, record the important place which the two ancestral families bore in the development of the cotton manufacturing industry; and Dr. Lowell, among his other many attainments, was a good business man, and served at one time as Acting Treasurer of the Massachusetts Cotton Mills and Treasurer of the Lowell Bleachery, also as Director and Trustee of several other companies. Through his success as a business man, he was able to finance and found the great Observatory at Flagstaff, which bears his name. In his younger days he resided in Tokio, Japan, and returned to the United States as special Counsellor of the first embassy sent by Korea to a Western power. His residence in Japan and Korea gave him an insight into Oriental thought which bore fruit in such sympathetic studies as his "Chosŭn," published in 1885; "The Soul of the Far East" (1886); "Occult Japan" (1894); and this happy faculty of the literary man enriched all of his subsequent scientific writings, which included "Mars" (1895); "Annals of the Lowell Observatory," Vol. I. (1898), Vol. II. (1900), Vol. III. (1905); "Mars and its Canals" (1906); "Mars as the Abode of Life" (1909); "The Evolution of Worlds" (1910); and numerous scientific articles describing notable scientific discoveries in the "Bulletins" of the Lowell Observatory, in current scientific magazines, and in the Proceedings of

Societies. He was made an Honorary Fellow of the Royal Astronomical Society of Canada, and received many other honorary recognitions of his distinguished services to science.

The work of the Observatory will be continued by the aid of a fund bequeathed by Dr. Lowell for this purpose; and by his wish the fund will be administered by his cousin, Guy Lowell, the architect of the New York Public Library, who was in full sympathy with him. The friends of Percival Lowell could ask for no more worthy memorial of him than the perpetuation of the work which he had at heart; and no better monument to his genius could be erected than the great observatory which he founded.

WESTWOOD, MASS.

THE GREAT AURORA OF AUGUST 26, 1916

IN this JOURNAL for October, 1916, were printed some good descriptions of this auroral display as seen at points in Ontario and in Alberta, and in the following number the magnetic curves reproduced (p. 511) showed that the magnetic disturbance began simultaneously at Agincourt and Meanook, which are over 1,500 miles apart. Since then much further information has become available, which it is proposed to summarize. The first part of this article will be a review of observations of the display, while the second part will contain an analysis of the magnetic curves recorded at the time.

PART 1.

REPORTS OF OBSERVATIONS OF THE DISPLAY

COLLATED BY C. A. CHANT

Long. 105° 45′ *W.*, *Lat.* 49° 48′ *N.* D. E. CHARTRAND, D.L.S. (Under date Aug. 27):—While taking an observation for declination last evening I noticed that the compass was extremely unsteady. . . . An unusually brilliant aurora was seen after the close of these readings, and I presume this is responsible for the disturbance. The approximate place of observation is N.E. Cor. Sec. 5, Tp. 10-28-2. Instruments used, Cooke D. L. S. Transit, No. 14316. It has a fairly sensitive needle.

[The readings given extend from 6.34 to 7.38 p.m., 105th Mer. time. At 6.57 the compass read 18° 40′ E.; at 7.15, 15° 42′; at 7.29, 19° 06′; showing an oscillation of 3° 24′ in 14 minutes.]

Barrie, Ont., A. F. HUNTER, M.A.:—At the time of the auroral display of Aug. 26, 1916, I was in Barrie, Ont., and witnessed it covering the greater part of the sky in patches, except at the remote south and west. There was no particular order that I could see, such as an arch; the auroral streamers seemed to shoot aloft here and there over almost the whole sky, wherever a cloud afforded an opportunity for the making of an electric discharge. It had been raining some in the afternoon, and there were clouds of the so-called "alto-cumulus" and "fracto-cumulus" orders still

floating in the sky,—and doubtless many cirrus clouds, but in the night one could not see them even with the light of the aurora. At the time I first witnessed the display, viz., 9.10 p.m. (E.S. Time), reddish or crimson tints were to be seen in some parts, being most intense in the west, at the southern limit of the lighted area.

Mr. W. E. W. Jackson, M.A., of the Meteorological Office, Toronto, supplies the following:—

Many descriptive reports of the Aurora, which was visible from all parts of Canada, have been received at the Central Meteorological Office from our observers. In Quebec and the Maritime Provinces only a very few witnessed the display on account of clouds, but from Ontario to the Pacific the weather was very fine and large numbers had the privilege of seeing the wonderful fireworks of nature. I have abstracted some of the observers' reports for the JOURNAL.

Vancouver, B.C.—Bright aurora from 8.15 to 10.30 p.m. Many streamers were of exceptional brilliancy, enabling numerous bright lines to be registered with the spectroscope. Corona formed near Vega at 9.30 p.m. A well marked auroral band extended from W. by N. to E. by S. at 8.30 p.m.

Victoria, B.C.—Fine aurora began at 8.30 p.m. with three coronal arches, one spreading to the zenith, and marked flashing extending from E. and W. towards the zenith.

Britannia Beach, B.C.—Class I. aurora but somewhat faint. Blue-green, yellow with a red-purple could be seen occasionally from 9 to 9.45 p.m.

Atlin, B.C.—Aurora almost to the southern horizon, partly colored corona. Magnetic trouble on telegraphic wire during the day.

Hudson's Hope, B.C.—Class I. aurora at 10 p.m.

Banff, B.C.—Exceptionally fine flashlight aurora.

Campsie, Alta.—Unusually brilliant display covering the whole of the sky. Colored.

Sion, Alta.—Extraordinary display covering the whole of the sky.

Medicine Hat, Alta.—Beautiful aurora north and extending south of east.

Anglia, Sask.—Waves and streamers to within 10° of south horizon and prismatic.

Manor, Sask.—Remarkably beautiful aurora all over sky.

Souris, Man.—Auroral arches well to the south.

Goodlands, Man.—Most remarkable and brilliant display radiating from the zenith.

Barrie, Ont.—10 p.m.—Shafts and flashes from far south of the zenith and brilliant cirrus-like formations near zenith. Light enough to read large print by. Flashes and shafts meeting above from all points of the compass evidence of tremendous magnetic power. At midnight 7/10 sky covered with nimbus clouds. Clouds lit up as by full moon. Whole sky light.

Steep Hill Falls, Ont.—Streamers and waves in all parts of the sky except east at 9.50 p.m.

Ronville, Ont.—Wonderful display extending to the horizon on all sides. Constantly vibrating with a large centre ring at zenith lasting from 8.15 to 9.35 p.m.

Beauceville, Que.—Apex 15° south of the zenith.

S.W.-Point, Anticosti, Que.—Aurora.

Port aux Basques, Nfld.—Very brilliant; sky covered.

Lake Douglass, Mich. In *Science* for October 6, 1916, appeared a fine description of the aurora, written by Prof. C. C. Nutting, of the State University of Iowa, which is reproduced in full:—

Between 8 and 9 o'clock on the evening of August 26th I stepped out on the porch of our cottage on the shore of Lake Douglass, in northern Michigan, and noticed what I at first mistook for an unusually bright twilight for that date and hour.

Looking up through the tree-tops I saw a curious flickering as of sheet lightning on a bit of cloud. But there was a peculiar streaming movement which at once suggested an auroral phenomenon, although I was looking towards the south! Passing around the house to an open field, I was fairly staggered with such a spectacle of light in motion as had never been dreamed of by any of our family group of eight which at once answered my cry of amazement.

Practically the whole vault of the heavens was alive with light. Light in patches, bands and arches; in streamers, sheets and delicate pencillings. Clear from the northern horizon to the zenith, and far beyond until the southern sky was invaded to within about four degrees of the horizon, and was utilized for the unfolding of the display.

I had seen what I thought to be fine auroras much farther to the north, but had never even heard of one which required almost the entire expanse of the heavens for its staging.

The focus of the spectacle was the zenith itself, and around this was a shifting and irregular zone of light below which almost the entire sky was set with masses of shifting, shimmering radiance constantly changing shape as if the sky were a vast kaleidoscope. It seemed, indeed, as if we stood beneath the centre of the dome of the firmament, whose vault was composed of bands and changing masses of streaming light, the quivering waves of which were surging upward toward the disk of blue at its apex. A brighter arch spanned the northern horizon, and this also was undergoing constant transformation.

It was not the light itself, marvellous as were its mass, zones, banners and streamers, that most thrilled the observers. Such a vast display of light in constant *movement* had never before been seen nor imagined by any of us. The whole heavens shuddered and staggered, shivered into a swirling chaos and reformed again and again in new and still more weird aggregates of shimmering light. Light streamed and wavered, rippled, flickered and pulsated. Now it was in broad waves reaching to the zenith, and now in vibrating bands. Here a broad cone shot up from the northern horizon until its apex pierced the very mid-heavens, and in the twinkling of an eye it was gone. There, from the shifting zones around the zenith, ripples of light passed upward to the blue apical disk. To the naturalist no more apt figure of this rippling motion could be suggested than the waves of light passing along the meridional bands of phosphorescent Ctenophora.

Again, a delicate fringe of pencil points would appear on the upper edge of one or more of the shifting zones and then shoot upward with inconceivable rapidity in sharp vibrating pencillings of light. As mentioned before, the focus of all these movements was the zenith itself, which seemed to be undergoing an intense bombardment of waves, ripples and searchlights from all sides, although subsidiary lateral movements were also in evidence.

Marvellous as was the rapidity of movement, the rapidity of change or kaleidoscopic effect was no less astonishing. Over and over again one of the observers would try to call attention to some particularly vivid display, only to find it utterly gone before the others could turn their eyes in the direction indicated. These changes were much more rapid than in other auroras seen by the writer. Nothing but electrical phenomena could approach their instantaneous shiftings.

At first the light was all pure white radiance, exactly that of elec-

tricity. Later certain areas took on a rose color, and still later the display more closely resembled that of ordinary auroras, being concentrated in the broad arch across the northern sky and showing more variety in colors.

So absorbed were the observers in this grand spectacle of light in motion that it was long before they noted the peculiar effect of the light upon themselves and their immediate surroundings. Then we saw that it was a perfectly diffused light, coming in practically equal intensity from all points of the sky. A more *unreal* scene could hardly be imagined. It was unlike moonlight, for there were no shadows nor shadings. On that account all objects seemed much less brilliantly illuminated than they really were. It was most like the light of early dawn; but still different for in the dawn the light, although diffused, is all from one side. Objects were distinctly visible, but flat. Our companions' faces could be seen quite plainly, but lacked individuality. The opposite shore of the lake could be seen much more distinctly than in bright moonlight and objects inside the house were quite distinct, even if small.

How long the display lasted we do not know, although one of the party reported it as striking as ever well past midnight. Finally the chill of the night and the aching of our strained necks drove us indoors with the conviction that never again should we see such a stupendous spectacle of light in motion.

Charlottetown, P.E.I.—Miss G. Messervy, B.A., states that the display was well seen at Charlottetown with the same general appearance as given by Nutting.

In *Science* for October 20, November 10 and December 8, a number of letters appeared containing information which may be summarized as follows:—

Chebeague Island, Maine.—L. M. Passano. Visible for many hours, until after midnight. Greatest intensity in zenith; light seemed to radiate and pulsate from east to west.

Annisquam, Mass.—Barry MacNutt. Auroras quite common this summer, but that of August 26th far surpassed any he had ever seen. Telephone and telegraph lines interfered with in eastern Massachusetts.

Rochester, N.Y.—Frank C. Baker. First seen at 8 o'clock and observed until after 10. Flickering and changing as described by Nutting.

Martha's Vineyard, Mass.—John W. Harshberger. Observed between 9 and 10 p.m. Somewhat dimmer than Nutting's description, perhaps due to observer being on seashore.

Wolfville, N.S.—PAUL R. HEYL. Same wide extent of display as given by Nutting, but brightness not so great. First seen as soon as it was dark, about 8 p.m., and observed until 10. Color uniformly a pearly white; no trace of any other tint.

Lucasville, Ohio, Lat. 39° N.—J. E. HYDE. It took the form of a bright, white, uniform illumination of the entire northern heavens, which extended in decreasing intensity almost to the zenith. Watched from 8.30 to 9.30 p.m., but no color bands, streamers, curtains, morning light waves, pulsations or other phenomena were observed, nor was any tendency to increase or diminish in brightness detected.

Mount Alexander Mackenzie, Long. 120° 27'W., Lat. 53° 57' N.—FRED. K. VREELAND. The display began about 8.30 p.m. (120th Mer. time), with the formation of a bow of light in the north, surmounting a dark area which suggested the Crookes dark space in a vacuum tube. This increased in brilliancy and was supplemented by other irregular bows or bands of light, crossing the sky from east to west. These were the principal sources of brilliant illumination, but in addition the whole sky, almost to the southern horizon, was swept with darting and shimmering beams and shafts and curtains of light. . . .

One of the most striking features was the weaving of curtains of light, appearing as if composed of parallel shafts or filaments, which brightened and paled in waves passing sometimes in one direction and sometimes in the other. These waving curtains interweaved in the most marvellous fashion, sometimes two or even three distinct and overlapping motions being visible in the same area, the shafts of light appearing to glide to and fro like the figures in a complicated but tremendously silent dance.

A little later the display took on the most varied colors, though this phase of the phenomenon was comparatively brief. The display ceased suddenly at about 9.45 p.m.

Chichagoff I., W. of Long. 136° and N. of Lat. 58°.—ERASTUS BRAINERD. The whole sky was covered, the play of the glow and the streamers was as rapid as that of heat lightning. The colors seemed to be of every shade of the spectrum, but changing rapidly. Display began about 7.30 p.m.

Glacier Bay, Alaska.—WILLIAM S. COOPER. The display began between 8 and 9 p.m. (135 Mer. time), when there was still considerable daylight. In its first appearance it was a sinuous band composed of pale green lances of light, seen first in the east, and winding over towards the west, fading into the still bright sunset light. This was shortly duplicated farther to the north; then four such bands were seen at once. Later, various colors

appeared in rapidly changing sheets, working towards the zenith. The climax came with a great burst of color directly above us, almost like an explosion, but remaining in full brilliancy for at least some minutes, constantly changing with marvellous rapidity. The colors included purples, heliotrope, pink, light and dark green. This burst faded away, then repeated itself, and faded again. During the remainder of the evening the lights were pale and diffuse.

Juneau, Alaska.—ALFRED H. BROOKS. Unusually brilliant. Observed from 8 to 10 p.m., but others state that it continued until nearly midnight.

Skagway, Alaska.—M. O. MALTE. The display of all the colors of the spectrum rushing together from all directions into a gigantic whirlpool in zenith, and then dispersing, lasted for at least half an hour.

Bristol, England.—W. F. DENNING. In *Nature* for August 31 and in *The Observatory* for October, W. F. Denning gives information regarding this aurora. Bright displays were observed from 10 to 10.20 p.m., Aug. 26th, at Totteridge, and on the following morning, 2.15 to 3.45, at Bristol (*i.e.*, 9.15 to 10.45 p.m., Aug. 26th, 75th Mer. time). Streamers reached an altitude of 70° in the northern sky. Before midnight the shafts of light exhibited a rapid horizontal motion from the E. to the W. side of the north point, while in the morning the direction of the drift was reversed, being from W. to E. Reference to some previous records indicates that this change of direction after midnight is a regular law, though for full confirmation further observations must be analyzed.

But the greatest source of information is the U. S. *Monthly Weather Review* for August, 1916. In it are reports from 67 stations in the United States. These range from Rhode Island on the east to Washington and Oregon on the west, and as far south as Virginia, Kansas and Utah (about lat. 37°N.). Quotations from a few of the reports follow.

Block Island, R.I.—An auroral display was observed from 8 to 10 p.m. (75th Mer. time). The altitude of the arch was about 20°, and the azimuth extended from about 120° to 220°. There were lively streamers of pale green ascending from a few degrees below the arch to an altitude of about 45°. The whole display was very brilliant.

Alpena, Mich. (*90th Mer.*). Beginning on the evening of the 26th and continuing into the morning of the 27th, one of the most magnificent, and to many awesome, auroral displays ever observed at this station was

witnessed. It was first noticed just after dark in the east. As darkness came on a great band of straw-colored light appeared across the firmament from east to west, spreading 40° north of the zenith and 10° south. This band of light had a steady movement to the southern horizon and reached it in about 20 minutes. By this time the whole heavens were covered with a sheet of whitish light which was bright and steady. Shortly this broke up into patches of iridescent light, which formed and vanished with tremendous speed in all parts of the heavens. Occasionally these patches were of indescribably fantastic shapes, joining and spreading to the zenith, forming a dome. The southern horizon was as bright as the northern. The display continued with irregular grandeur until sometime after 2 a.m. Many people who were on Lake Huron spoke of the beautiful reflection of the display from the water.

Peoria, Ill. (*90th Mer.*). A striking display of aurora borealis, composed of glow and streamers with considerable drifting, flashing, dancing and flickering. Coloring generally whitish, with a little rainbow tinting about 9 to 9.15 p.m A noticeable drifting from about east-northeast and at the same time a southward shift of the whole formation. About 10 p.m. the front or higher portion of white streamers had formed a sort of band near the zenith, extending from about azimuth 95° to azimuth 280°, while the display farther north had decreased in brilliance. (Perhaps this band-like appearance was due to perspective of streamers standing nearly vertical to the sky.) Later the band formation shifted 10° or 15° south of the zenith, retaining its original trend. A westward drift within the band was at all times noticeable, but the band at no time reached lower in the west than altitude 40°.

Minneapolis, Minn. (*90th Mer.*). An unusual auroral display was observed beginning shortly after 8 p.m. It then covered the northern half of the sky from azimuths 80° to 280°. The display took on several forms. There were several more or less well-defined arches in the north-northeast, with streaks and streamers pointing upward from the east, north and west and converging at a central point or apex about 10° south of the zenith, where the streaks of light were of shorter length and arranged themselves around this apex similar to pieces of iron filings in a field of magnetic force. There were also patches of irregular cloud-like masses of light scattered over the northern sky. Very few of the streamers had any "shooting" upward motion, but there was a continuous wave-like motion from all sides toward the apex running over the light places and streaks. The display continued until after midnight with varying intensity. There

were no eastward-westward motions along the arches and very little coloring.

Walla Walla, Wash. (120th *Mer.*). An auroral display was witnessed between 8 and 10.30 p.m. A broad arc of white light extended above the horizon, its centre being east of Polaris. Vertical streamers of light shot up at intervals above the bands of white light, being at times so numerous as to form a curtain of light across the northern sky. The display was quite brilliant during the first hour.

Modena, Utah (105*th Mer.*). A faint aurora was observed at 10.30 p.m. of the 26th and ending during the morning of the 27th. It consisted of vibrating streamers which reached to an average height of 30°. The streamers seemed to radiate from a point below the horizon directly in the north and extended along the horizon 20° from each side of azimuth 180°.

Warren, Va. (75*th Mer.*). At 9.05 p.m. the sky became remarkably bright low down and on my western horizon and had the appearance of dawn, for the sky became streaked with a pale yellow glow. From a central point of this glow a spear of light gradually lengthened and by 9.30 p.m. it had taken the appearance of a searchlight beam. Simultaneously red lights appeared and faded on the northwestern horizon, reaching a short distance upward and extending perhaps 2° horizontally, about reaching my meridian.

At 10.15 p.m. the shaft of yellow light was unusually brilliant and began to widen until it was as wide as in the Milky Way, which it crossed. The beam became vapory and film-like as it broadened, but when it again narrowed at 10.25 it was intensified and resumed the shape of a searchlight beam. At 10.25 it began to fade rapidly and had completely vanished at 10.30 p.m. About 1 a.m. next morning a red glow appeared in the northwest and north, fading away in a few minutes.

From all the available reports it appears that the display was seen from N. Latitude 37° to that of Alaska. In Ontario, Michigan, Wisconsin and Minnesota it covered the entire sky, was in continual motion, and was very beautiful, though there was present little of the vivid coloring seen in more northerly parts of the continent. In the latitude of Virginia and Utah the illumination of the sky was mostly in the north and the more striking features observed in higher latitudes were absent. The

display probably began everywhere at the same absolute time, as the magnetic storm accompanying it seemed to break out simultaneously at the various recording stations in the United States and Canada. (See part II., following).

In *Science* for November 17 is an important paper by Prof. C. C. Trowbridge, of Columbia University, who observed the aurora from a station on the north shore of Prince Edward Island (Lat. 46° 26′ N., Long. 63° 8′ W.), and who paid especial attention to the location of the focus of the auroral streamers. This apparent meeting of the streamers he considers to be simply due to perspective, that the streamers are in reality parallel to each other and seem to come together at this point. (See report from Peoria, above.) Some extracts from the paper follow:—

The writer was on a wide stretch of water and observed the beginning of the aurora, which occurred at 8.15 p.m., Atlantic time, the sky being perfectly clear. The glow at first showed dimly in the southern sky, but rapidly increased in intensity until the entire southern portion of the vault of the heavens was pierced by pale, greenish, lance-like streamers. Those overhead terminated in a well-defined focus, southeast of the zenith, as shown in Fig. 1.

For some minutes there was no evidence whatever of an aurora to the north. Later, streamers rose in that section, and soon the entire sky had the appearance of a luminous umbrella, the well-defined centre of which was southeast of the zenith. A short time after the commencement of the aurora a band-like corona* stretched across the greater portion of the heavens from east to west through the focus, as shown in Fig. 2, and at another time a large irregular corona formed around that region of the sky.

The auroral glow showed the very rapid kaleidoscopic changes described by Professor Nutting and the phenomenon was indeed inspiring on account of the unusual grandeur of the display. The color of the streamers as seen from Prince Edward Island throughout the entire evening was pale greenish, almost white, and at no time reddish or the intense light green frequently observed.

The earth appeared as if illuminated by bright moonlight, except the

*I would call this an auroral band, not a corona.—C. A. C.

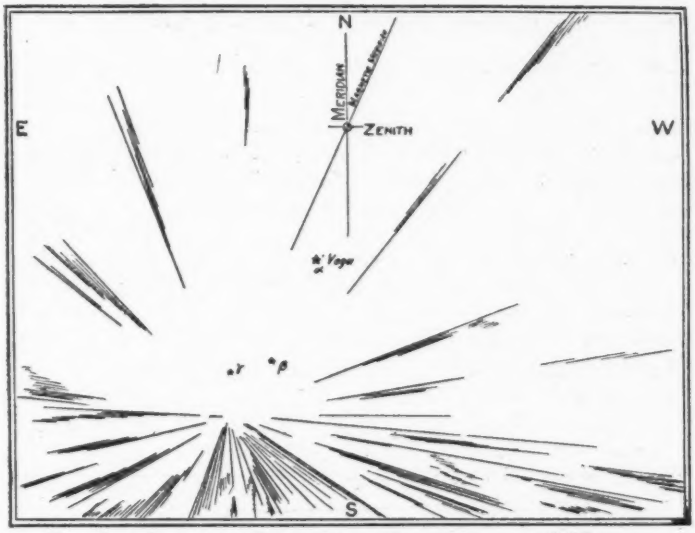


FIG. 1.—AURORAL FOCUS AS IT APPEARED AT 8.20 P.M., AUGUST 26, AT PRINCE EDWARD ISLAND.
(The heavens are shown as they appear when facing the south and looking at the zenith).

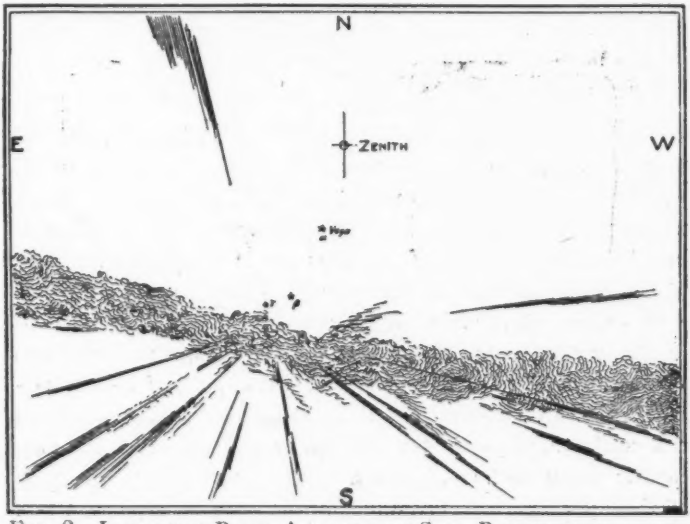


FIG. 2—LUMINOUS BAND ACROSS THE SKY, PASSING THROUGH THE FOCUS, AS OBSERVED ABOUT 8.25 P.M.

striking effect due to the absence of all shadows, as already reported by Professor Nutting. . . . .

An aurora was observed by the writer some years ago, on September 11, at Grand Lake, Maine, which completely arched the southern sky with bright streamers. That display began about 8 o'clock p.m. and lasted several hours. At first, no auroral phenomenon appeared north of the zenith, but as the evening advanced a faint glow was seen in the north. Particular note was made at the time that the streamers in the southern as well as the northern sky appeared to meet a considerable number of degrees to the southeast of the zenith, but the exact location was not observed. One fact of similarity between these two appearances of the aurora in the southern sky was that in both cases the streamers appeared in the southern half of the heavens before any indication of an aurora showed in the north; as if some condition of the atmosphere susceptible to an auroral display had been reached to the south before it had been reached to the north of the point of observation, indicating some progressive change in the atmosphere from south to north.

The position of the apparent focus of the streamers near the zenith is of special importance owing to the relation of the direction of the streamers to the direction of the lines of force of the magnetic field of the earth. The point of focus was located about 2° south of the star Gamma Lyræ at 8.20 o'clock, Atlantic time. The spot in the heavens could apparently be located within an area of the size of the full moon. . . . The zenith distance of the auroral focus thus determined is 16° 54′ and the azimuth of that point 22° 42′ E.

Prof. Trowbridge compares the position of the focus with the magnetic zenith, i.e., the point to which the dipping needle points, and he finds they agree to within about 2°. Assuming that this aurora was at the average height of auroras measured by Störmer, namely, about 65 miles, Trowbridge remarks that his study of meteor trains has shown that they ordinarily occupy a definite zone between 50 and 70 miles above the earth. Thus, it seems to be shown that there is a zone in the atmosphere susceptible to electrical conductivity, beginning at about 50 miles from the surface of the earth. Other considerations lead to the view that there is a conducting layer in the atmosphere through which the long electric waves used in wireless telegraphy pass easily. Probably all these phenomena are produced in the same atmospheric layer.

PART II.

The Magnetic Storm of August 26, 27, 1916

By W. E. W. Jackson

In view of the interest aroused by the aurora on the night of August 26, I thought it might be advisable to make a detailed analysis of the curves obtained at Agincourt and reproduced in the Journal for November, 1916 (page 511), and in order to broaden the inquiry application was made to the U. S. Coast and Geodetic Survey for copies of the magnetograms obtained at their magnetic observatories on the same date. Mr. R. L. Faris, acting superintendent, very kindly supplied the curves for Sitka, Cheltenham, Tucson and Honolulu, together with the necessary data for making correct measures of the magnitude of the disturbance. I gladly take this opportunity to express to Mr. Faris my sincere thanks.

The following table gives the latitude and longitude and approximate values of the magnetic elements at the observatories whose records are analyzed in this paper.

D = Declination, H = Horizontal Force, Z = Vertical Force.

Observatory	Lat. N.	Long. W.	D	H	Z
	° ′	° ′	° ′	γ	γ
Sitka	57 03	135 20	30 24 E.	15520	55890
Meanook	54 37	113 20	27 49 E.		
Agincourt	43 47	79 16	6 34 W.	15978	58510
Cheltenham	38 44	76 51	6 08 W.	19300	55020
Tucson	32 15	110 50	13 45 E.	27040	45810
Honolulu	21 19	158 04	9 45 E.	28960	23830

The beginning of the disturbance is very abrupt in H and D at all stations though not so pronounced in two, namely, at Cheltenham and Tucson. Measures were made of the time of occurrences of this abrupt movement on each trace and the value given below for each station is the mean of the times for the three elements:

	75th Mer. Numbering from Midnight
Sitka	14h. 43.5m.
Meanook	14h. 42.0m. (*D* only.)
Agincourt	14h. 42.9m.
Cheltenham	14h. 43.1m.
Tucson	14h. 43.1m.
Honolulu	14h. 43.2m.

In *Nature* for September 21, 1916, a report on this storm states that the time of commencement at Eskdalemuir and Kew was about 7.45 p.m. G.M.T. = 14h. 45m., 75th Mer. Time.

The agreement in these times is fairly good evidence that the storm made itself felt practically instantaneously over the world. One hour is represented on the trace by only from 15 to 20 mm.

The maximum variations in *D*, *H* and *Z* are given in the following table:

	D	H	Z
		γ	γ
Sitka	2 48·0 *a*	1020	977 *b*
Meanook	3 38·8		
Agincourt	3 18·5 *b*	889 *b*	618 *b*
Cheltenham	1 10·1	621	450
Tucson	0 26·6	305	48
Honolulu	0 28·8	317 *b*	99

a. Value uncertain. Trace very faint.

b. Beyond limit of paper, value estimated.

In order to examine minutely the changes which took place in the impressed force the following method has been employed. A zero line was drawn on the curves showing the normal condition, and the departures from this curve were measured in tenths of millimetres. The ordinates so obtained were multiplied by the constants which express the number of γ corresponding to 1 mm. of the ordinate for *H* and *Z*, and for *D* by the change in Force in λ in E.W. direction necessary to produce a change of 1 mm. of

ordinate. The superposed disturbing Force in a vertical direction, dZ, is considered positive towards the centre of the earth, that in the horizontal magnetic N.S. direction, dH, positive towards the N. and that in horizontal magnetic E.W. direction, dD, positive towards E.

dD, dH, and dZ are calculated for every half hour from August 26, 14h., to August 27, 3h. and at the hour for August 27, 4h. and 5h.

The values so obtained for dD and dH have been transformed to dX and dY (rectangular co-ordinates in the tangent plane at the place in geographic N. and E. directions), dX positive towards the N, and dY positive towards the E.

E. declination being considered positive, the above transformation is made by the following formulæ:

$$dX = dH \cos \delta - dD \sin \delta,$$
$$dY = dH \sin \delta + dD \cos \delta.$$

dX, dY, and dZ were then projected on the axis of an orthogonal co-ordinate system with origin at the centre of the earth. In this system let the X' axis coincide with the earth's polar axis and let dX' be positive towards the N. Let the Y'-axis and Z'-axis be in the equatorial plane with the Y'-axis intersecting the equator at 90°E longitude, positive towards the 90° point, and Z'-axis at 0° longitude, dZ positive towards the 0° point. If ϕ and λ represent the geographical latitude and longitude of the place of observation, positive North of the Equator and East of Greenwich, then the transformation is made by the following formulæ:

$$dX' = \cos \phi \, dX - \sin \phi \, dZ$$
$$dY' = - \sin \lambda \sin \phi \, dX + \cos \lambda \, dY - \sin \lambda \cos \phi \, dZ$$
$$dZ' = - \cos \lambda \sin \phi \, dX - \sin \lambda \, dY - \cos \lambda \cos \phi \, dZ.$$

Let R be the resultant impressed force and ϕ' and λ' the latitude and longitude of the point where the resultant cuts the surface of the earth then

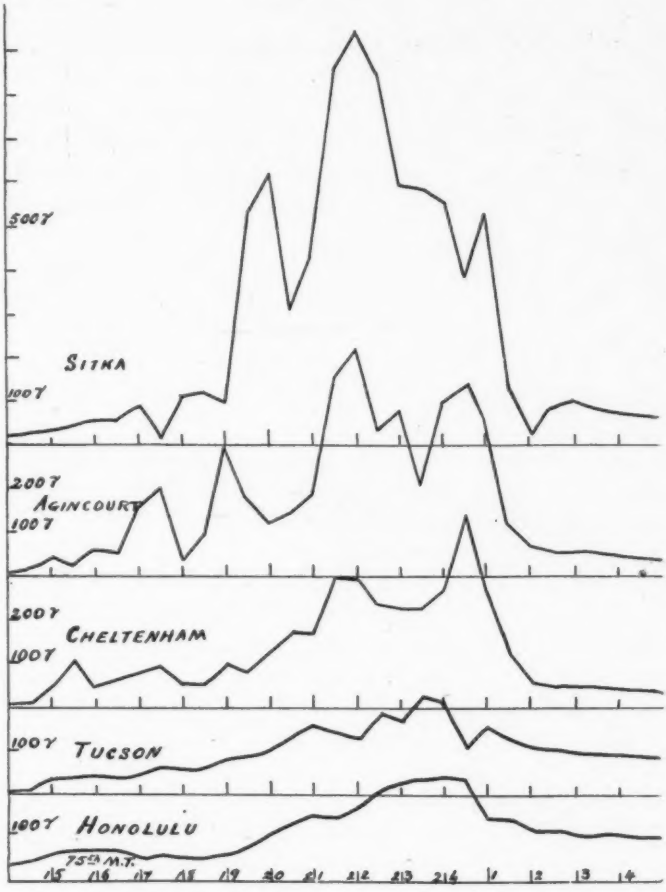
$$R = \sqrt{dX'^2 + dY'^2 + dZ'^2},$$

75th Meridian Time		Sitka			Agincourt			Cheltenham			Tucson			Honolulu		
		R	ϕ'	λ'	R	ϕ'	λ'	R	ϕ'	λ	R	ϕ'	λ'	R	ϕ'	λ'
h	m	γ	°	°	γ	°	°	γ	°	°	γ	°	°	γ	°	°
Aug. 26 14	00	24	12	- 112	10	76	- 109	6	59	18	6	10	45	38	34	135
	30	28	32	73	11	56	- 60	10	61	0	10	24	41	48	41	138
15	00	29	59	23	41	59	100	43	59	108	37	66	48	64	67	108
	30	45	43	35	24	74	122	104	59	119	38	60	52	69	64	120
16	00	55	16	- 48	65	48	124	46	54	132	40	58	133	71	61	119
	30	51	42	23	47	41	165	69	54	149	35	66	135	71	56	125
17	00	91	4	- 67	154	37	124	82	27	138	44	12	157	50	35	141
	30	12	0	81	204	15	111	94	- 20	144	62	- 22	168	58	8	140
18	00	109	- 5	91	39	3	108	58	- 23	166	55	- 44	- 161	54	- 7	135
	30	123	- 6	45	93	- 22	139	56	- 67	117	58	- 12	167	50	- 4	130
19	00	99	- 30	31	301	25	104	104	- 58	95	87	- 26	165	63	- 29	139
	30	533	2	15	175	- 18	- 80	79	- 37	- 38	92	- 62	164	77	- 31	141
20	00	612	10	19	119	- 20	- 76	125	- 32	- 7	100	- 85	63	107	- 43	146
	30	303	5	20	144	35	59	166	- 36	- 2	140	- 69	164	132	- 57	154
21	00	436	47	15	191	- 10	- 51	167	- 37	- 43	156	- 87	- 173	151	- 58	153
	30	855	57	15	453	- 22	- 91	297	2	- 48	135	- 77	- 18	146	- 62	155
22	00	933	65	8	509	- 21	- 108	294	- 1	- 66	112	- 65	- 15	171	- 64	159
	30	846	69	- 9	339	- 27	- 99	232	4	- 67	185	- 73	- 40	209	- 58	159
23	00	590	72	- 119	381	- 18	- 92	224	- 10	- 72	167	- 85	- 113	227	- 62	158
	30	588	67	- 111	200	- 34	- 66	226	- 31	- 44	221	- 76	- 118	233	- 61	156
24	00	564	60	- 147	389	- 50	- 76	262	- 28	- 43	215	- 79	- 177	236	- 62	157
Aug. 27	30	378	35	159	431	- 59	- 105	439	- 25	- 79	100	- 29	1	226	- 72	169
1	00	527	28	- 149	353	- 30	- 105	256	- 13	- 83	153	- 47	165	141	- 72	156
	30	159	65	- 125	115	- 46	- 21	124	- 38	- 38	121	- 53	161	141	- 64	150
2	00	29	84	- 18	67	- 27	36	56	- 39	27	106	- 72	164	123	- 61	144
	30	83	- 11	- 167	55	- 78	51	46	- 58	48	99	- 70	155	116	- 61	141
3	00	101	- 5	- 173	58	- 67	27	47	- 57	48	97	- 70	153	111	- 61	141
4	00	70	- 7	- 172	48	- 54	- 42	39	- 58	36	89	- 72	149	103	- 62	139
5	00	63	- 17	- 163	45	- 57	- 57	34	- 60	10	84	- 74	154	98	- 63	138

$$\tan \phi' = \frac{dY''}{\sqrt{dX''^2 + dZ''^2}},$$

$$\tan \lambda' = \frac{dY''}{dZ''}.$$

The values obtained for R, ϕ' and λ' for the different observations are given in the adjoining table, and the changes in the magnitude of R for each place is also shown graphically in the figures.



Resultant Impressed Force, Aug. 26-27, 1916.

CURVES EXHIBITING THE STRENGTH OF THE MAGNETIC STORM OF AUGUST 26-27, 1916

The resultant is directed more or less northerly at first and gradually swings around until it takes up a position towards the earth's south magnetic pole. The impressed force increased in strength very gradually up to 19 hours and then at the more northerly observatories the increase was quite rapid until the maximum was reached at 21 hours, followed by a secondary maximum between 24 hours and 1 hour. At Cheltenham, Tucson and Honolulu the maximum was not reached until about 24 hours. The decrease up to 2 hours was very pronounced, after which the resultant gradually diminished.

THE QUESTION OF THE PRESENCE OF HAZE SPECTRUM IN THE MOUNT WILSON OBSERVATIONS OF THE SOLAR ROTATION

By Ralph E. De Lury

IN the December number of this Journal appears* a note by Messrs. St. John and Adams, in which is discussed that point of my paper on "The Effect of Haze on Spectroscopic Measures of the Solar Rotation," where, to explain the differential effect accompanying variation in the character of the spectrum line, the possible explanation is advanced† that there was present a considerable strength of blended haze spectrum in the Mount Wilson observations‡ of the sun's rotation in 1914-15. In their note is given the result of a test which showed that "for equality of blackness of the two spectra it was necessary to make the exposure from the point just off the disk 100 times as long as for the edge of the disk itself"; and from this the deduction is made that "the light scattered by sky, haze and instrument did not exceed one per cent. of the light from the edge of the disk." This deduction would seem to have been made overlooking the fact that the density of the negative is proportional to a power of the time usually within the range of 0.6 to 0.9. If for the plate used in the test the exponent of the time was 0.6, 0.7, 0.8 or 0.9, then the scattered light was 6.3, 4.0, 2.8 or 1.6 per cent. of the light from the limb of the sun,—a probable value being about 4 per cent. Such a strength of scattered light would, under the conditions of my measurements, produce about half the effect noted in the Mount Wilson observations; but, under the different conditions of those observa-

* Vol. X., p. 553, 1916. † Ditto, p. 353.

‡ *Popular Astronomy*, Vol. XXIII., p. 641, 1915.

tions (measurements, plate fog, etc.), it could conceivably account for an effect of the magnitude observed. In the absence of exact information concerning the extent of haze in the Mount Wilson 1914-5 observations, it is of scientific interest that the criteria which I have suggested in the paper mentioned be applied to them. As I have pointed out, the results of future observations of the solar rotation, accompanied by measurements of the amounts of scattered light, should settle the question as to the terrestrial origin of the observed differential effect; "but if in any series of observations the terrestrial haze spectrum can be proven of insufficient strength," then it may be possible to account for the differential effect by assuming the production of a spectrum of non-rotating matter in the solar atmosphere,—in fact the possibility of detecting such matter was one of the reasons for undertaking the measures of blended spectra. It may be mentioned here that in using the word "haze" I regarded the variable cirrus hazes as likely to be the chief source of scattered light; and, of course, from the effects of these hazes no observatory is immune.

Solar Physics Division,
Dominion Observatory, Ottawa,
December 15, 1916.

MEETINGS OF THE SOCIETY

At Toronto

Nivember 14, 1916.—A regular meeting of the Royal Astronomical Society of Canada was held in the rooms at 198 College St., this evening, the President, Dr. Watson, in the chair.

A communication from Ottawa Centre was read, embodying a resolution passed at their last meeting, recommending to the general Council that the fees of the members of the Society who have enlisted and those who are serving overseas be remitted so long as they are in the service. Moved by Mr. Collins, seconded by Professor Chant, that the Ottawa resolution be supported by the Toronto meeting. Carried.

M. Ste. Marie, 57 Park Ave., Montreal,

T. S. H. Graham, Clinton, Ont.,

were elected members of the Society.

Under "Observations" Mr. Hunter reported the observation of mock suns on the afternoon of Saturday, Nov. 11th. The solar halo was noted to be intense from 3 to 4.20 o'clock. The sunset effects and afterglow he thought to be unusually intense of late.

Mr. Blake reported but slight disturbances on the sun's surface at the present time.

Dr. Watson read quotations from Virgil that went to show that in his time the audibility of the aurora was believed in.

Professor Chant referred to the loss astronomy had sustained by the death of Dr. Percival Lowell, Director of the Lowell Observatory, and but lately elected Honorary Fellow of this Society.

A review of his work, it was announced, will appear in a forthcoming issue of the JOURNAL.

The paper for the evening was by Sir Frederic Stupart, Director of the Meteorological Service of Canada, on "Is the Climate Changing?" According to the facts and figures presented to the Society he drew the conclusion that within historical times the climate is not changing, unless it be by very minute quantities. There may be a slight tendency towards warmer summers and reduced rainfalls. The lecturer referred to climatic conditions as traced and determined through the growth of trees and fruits in California and Palestine, indicating the probability of the small pulsations in climate as being world wide. He also referred to the records of the Jesuits on the weather of Canada during the period of the French occupation, showing droughts, heat and cold as we have them at present.

W. E. W. JACKSON, *Rec.-Sec.*

AT OTTAWA

October 20, 1916.—The first meeting of the fall term was held in the Geodetic Survey Building, at 3 p.m. Mr. A. J. Ames was duly elected a member of the Society.

The paper for the meeting was a report by Mr. W. E. Harper on the annual meeting of the American Astronomical Society which met in Swarthmore at the Sproul Observatory. Mr. Harper had already prepared a report to be sent to the JOURNAL and his lecture was intended to supplement rather than duplicate that report. He presented the new method of determining the parallax of stars devised by Adams and Kohlshutter. This is a spectroscopic method and has given results which are in close agreement with those obtained by the other older methods. It requires further direct observations of parallax of the low proper motion stars to fix the curves. Furthermore, it is applicable only to stars of *F* and succeeding types as in them only are the line variations pronounced. In concluding, Mr. Harper referred to the work which has been done of late years on nebulæ and which was re-

ported on at the meeting. This has special reference to the high velocities obtained for spiral nebulæ.

October 27.—The second meeting of the fall term was held in the Carnegie library, at 8 p.m.

The lecturer for the evening was Prof. W. H. Day of the Guelph Agricultural College, who spoke on the subject of "Lightning," The lecture was divided into three parts, theory, practice, and statistics. It was profusely illustrated by experiments and a number of beautiful slides of photographs of lightning taken by Mr. Steadworthy were shown.

In his discussion of the theory Prof. Day showed by experiment that there were two kinds of electricity and that they are governed by certain laws of attraction and repulsion. The lecturer took pains to go into the most elementary parts of this subject and the interest of those present showed that he was well able to handle this part which might have been expected to be rather tedious.

Prof. Day then set up a model house and by changing the conditions under which it was placed showed that the electric current in the lightning followed the theoretical laws. He showed that lightning rods were a marked protection to houses; barns and fences as well, but that all metal parts of the buildings must be connected to the rods and that the rods must be provided with sharp points which must be kept pointing straight up. He showed that such points actually prevent much of the discharge. Another interesting point brought out was that thunder clouds tend to drift close to the earth because of the attraction of the charged earth for the charged cloud.

In his discussion of the statistics, Prof. Day showed that actual figures collected by insurance companies of Ontario and some American companies showed that lightning rods were from ninety to ninety-eight per cent. efficient. He gave statistics which he claimed proved that the rods prevented a large percentage of the probable strokes.

After the lecture a discussion began on various points touched on in the lecture and the length of this was sufficient to show the great interest developed by the address.

November 10.—The third meeting of the fall term was held in the Geodetic Survey Building, at 3 p.m.

The lecture of the afternoon was given by Mr. J. L. Rannie on the subject, "A Short History of Geodesy."

The early investigations, discoveries and developments, were first discussed by Mr. Rannie. The discovery by Pythagoras of the sphericity of the earth and the proofs given by Aristotle were of interest in that the method of proof was that of to-day, the disappearing ship, the shadow of the earth in an eclipse, etc. The measurement of an arc of a meridian by the Egyptians about 300 B.C. gave a result of about 29,700 miles for the circumference of the earth and was made by finding the meridian altitudes of a star at the two ends of a measured base. A measure by the Arabians was made about 700 years later by two parties moving, one north and the other south and proceeding until the pole star had changed by a degree. The results of these last measures was not good, however. Then came the circumnavigation of the globe and a renewed interest in the question.

A new era began when Snell attempted to arrive at the values of the sizes of the various measurements by means of a triangulation network. This was made before there had been any vernier or micrometer or a telescope fitted with cross hairs. In 1669 Picard adapted the theodolite with cross hairs in the eye piece; and using the vernier, which had been invented in the meantime, he measured an arc in France. We are, however, unable to determine how exact these measurements are as we do not know the exact values of his units.

The modern era began when a controversy arose as to whether the earth were an oblate or a prolate spheroid. Ricard's clock which kept correct time at Paris was out when taken to the tropics a matter of a couple of minutes a day. Newton's dis-

covery of the law of gravitation led to the belief of the oblateness of the spheroid. Two expeditions were accordingly arranged by the French, one to Peru and the other to Lapland. The results of these expeditions established the fact that the earth was of the form of an oblate spheroid.

The improvements in the theodolite until it was of sufficient accuracy to detect the spherical excess in the triangles and the working out of the Theory of Least Squares by Gauss gave the Science of Geodesy the working materials for the modern accurate work. Arcs have been measured in various parts of the earth by different governments and carried to considerable lengths. These are being correlated and it is hoped that the measures may be made to come out with great precision. It has been established that the earth has the form of an oblate spheroid and it has also been found that it possibly differs from this form in that the plane of the equator is not quite circular, but slightly eliptical. The measures are, however, so contradictory and uncertain that it is generally taken that the earth has the simple form.

There are four measures, or, as they are called, four spheroids. Bessel's, Clarke's of 1866, Clarke's of 1878, and that of the U. S. Coast and Geodetic Survey. The spheroid used in Germany is that of Bessel. That used in Canada is that of Clarke for 1866.

The subject of Isostasy is one that takes up a good deal of attention in modern Geodesy. Modern measures must be carried out very carefully in order to give the necessary data for furnishing the values of the depth, etc., of the suspected isostatic layer.

The lecture closed with a discussion of the relative values of arc and area surveys with the preponderance of value in favor of the latter. The matter of the datum of a survey was also briefly discussed.

The lecture was very interesting and was much enjoyed by the members present, of whom there were an unusual number.

E. A. Hodgson, *Secretary*.

NOTES FROM THE DOMINION OBSERVATORY

SEISMOLOGICAL TABLES

The following notice of the Seismological Tables by Dr. Otto Klotz. (*Publications of the Dominion Astronomical Observatory*, Vol. III., No. 2.) appeared in the *Seismological Bulletin* over the initials J. B. W.

Dr. Klotz has done a service of inestimable value to American seismologists in publishing a hand-book of tables for the complete interpretation of seismograms in accordance with the most recent determinations of the velocity of seismic vibrations. Before the publication of this set of tables, those in charge of seismographs who were fortunate might have had for use the table worked out by Dr. Zeissig for distances from the times of P and S up to 13,000 kms.; but for determining the time at origin no satisfactory tables were available. Dr. Klotz's tables include the valuable data elaborated by Dr. Mohorovicyc, Agram in Hungary, the most accurately determined constants for transmission of P and S from the epicenter up to the determinable distance of 13,000 km. Unfortunately, satisfactory data are wanting to assuredly determine distances above 13,000 kms.

The tables employ Wiechert's admirable symbols, which have now everywhere replaced, by international agreement and tacit consent, the earlier systems invented by Milne, Laska, and others.

In addition to the speed constants above referred to, the tables include data for correctly determining the amplitude of maximum motion among the L waves of a seismogram when the instrument has been properly damped. It is useless to publish

the amplitude of undamped records, as is still a common practice. Lastly, among other useful aids to station work, the tables give the constants for locating an epicenter from a large number of North American and foreign stations according to the graphic method devised by Dr. Klotz.

With these tables in his possession even the amateur in charge of a seismograph can make accurate contributions to our knowledge of a well-recorded earthquake, provided his clock is correct to a second and he knows how to identify the phases of an earthquake recorded by a seismogram.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

November, 1916

Temperature. — The mean temperature of the month was above average throughout the Western Provinces, and below average in British Columbia and from Ontario eastward. The largest positive departure 6°, occurred in Northern Saskatchewan, and the largest negative, also 6°, in Northern British Columbia, while in Nova Scotia the negative departure was from 3° to 4°.

Precipitation. — The precipitation was less than average in nearly all parts of the Dominion, the only districts in which there was an excess being the Lower St. Lawrence Valley and the immediate vicinity of the Georgian Bay. The largest deficiencies occurred in British Columbia, exclusive of the extreme north, and in Saskatchewan, Manitoba and Nova Scotia, in each of which Provinces the total aggregate was about half of the average amount. At the close of the month the northern interior plateaus of British Columbia were snow covered, as were also the districts north of the Great Lakes and north of the Gulf of St. Lawrence, but nearly all the Dominion was bare of snow.

Temperature for November, 1916

Station	November		Station	November	
	Highest	Lowest		Highest	Lowest
Yukon			Kenora	59	4
Dawson	44	-14	Kinmount		
British Columbia			Kingston	58	9
Atlin	47	- 4	Kitchener	66	12
Agassiz	56	25	London	67	12
Barkerville	39	-13	Lucknow	63	12
Kamloops	57	5	Markdale	66	9
New Westminster	52	21	North Gower	65	- 8
Prince Rupert	56	24	Oshawa		
Vancouver	53	23	Ottawa	63	- 1
Victoria	52	29	Paris	66	10
Western Provinces			Parry Sound	62	4
Battleford	61	- 0	Peterboro'	65	6
Calgary	56	-10	Port Arthur	55	- 2
Edmonton	52	- 8	Port Burwell		
Medicine Hat	68	-12	Port Dover	62	11
Minnedosa	50	- 5	Port Stanley	59	13
Moose Jaw	62	- 9	Queensborough	64	- 2
Oakbank	57	- 4	Ronville	65	- 5
Portage la Prairie			Southampton	62	11
Prince Albert	58	- 4	Sundridge		
Qu'Appelle	57	- 6	Stonecliffe	68	-10
Regina	59	- 8	Stony Creek	69	13
Saskatoon	57	- 2	Toronto	64	12
Souris	61	- 3	Uxbridge	63	- 1
Swift Current	60	-12	Wallaceburg	66	12
Winnipeg	57	0	Welland	68	13
Ontario			White River	52	-27
Agincourt	66	8	*Quebec*		
Aurora	65	2	Brome	65	0
Bancroft	54	- 8	Father Point	55	7
Barrie	69	3	Montreal	64	2
Beatrice	66	- 4	Quebec	63	- 4
Bloomfield	59	6	Sherbrooke	65	4
Brantford			*Maritime Provinces*		
Chapleau	52	- 9	Charlottetown	52	16
Chatham	69	17	Chatham	64	2
Clinton	67	14	Dalhousie	45	- 4
Collingwood	69	6	Fredericton	66	- 5
Cottam	66	8	Halifax	60	10
Georgetown	67	5	Moncton	66	- 1
Goderich			St. John	54	9
Gravenhurst			Sussex	61	-12
Grimsby	60	13	Sydney	56	16
Guelph	66	14	Yarmouth	56	16
Haliburton	65	9			
Huntsville	67	- 8			

MAGNETIC OBSERVATIONS

October, 1916

The photographic records of the magnetic forces for October show a considerable diminution of activity, particularly during the latter half of the month both at Agincourt and Meanook. Moderately large disturbances were, however, recorded on the 1st, 6th to 8th, 13th and 22nd, the second of which was most noteworthy. In this disturbance the period of greatest activity at Agincourt occurred between 19^h and 23^h of the 6th (75th M.T.) whilst at Meanook, the movement in *D* was quite similar to the *D* at Agincourt, during these hours, yet greater oscillatory movements occurred during the night hours, and particularly after local midnight of each day. The 4th, 16th to 19th, 27th and 28th were classified as quiet days.

A sun spot group that crossed the centre of the sun's disk about the 14th displayed great activity.

AGINCOURT MAGNETIC OBSERVATIONS

Lat. 43° 47′ N.; Long. 79° 16′ W.

October, 1916		D. West	H	Z	I
		° ′			° ′
	Mean of Month	6 34·4	0·15967	0·58523	74 44·3
	Maximum	7 28·2	0·16186	0·58750	
	Date of Maximum	6	6	13	
	Minimum	5 39·2	0·15664	0·58336	
	Date of Minimum	6	6	6	
	Monthly Range	1 49·0	0·00522	0·00414	
Mean Daily Amplitude	From hourly readings	0 9·1	0·00047	0·00028	
	From means of extremes	0 22·6	0·00096	0·00057	

H and Z are expressed in C.G.S. units. (1γ = 0·00001 C.G.S.).

All results are reduced to I.M.S.

MEANOOK MAGNETIC OBSERVATIONS

Lat. 54° 37′ N.; Long. 113° 21′ W.

October, 1916		D. East	I
	Mean of Month	° ′ ″ 27 48·8	° 77 56·4
	Maximum	29 55·2	
	Date	6	
	Minimum	26 26·2	
	Date	7	
	Monthly Range	3 29·0	
Mean Daily Amplitude	From hourly readings	0 10·2	
	From means of extremes	0 43·0	

All results are reduced to International Magnetic Standard.

The value for I is the mean of all the observations made during the month without regard to the time of day.

W. E. W. J.

Earthquake Records by the Milne Seismograph

TORONTO

Sir Frederic Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1916	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm.	
1653	Nov. 3			22 40·8		22 52·1	0·2	Gradual thickening.
1654	" 10			9 29·1	9 29·5	9 39·0	0·3	P. and S. not recorded.
1655	" 11			14 18·1	14 23·5	14 51·7	0·4	Gradual thickening. P. and S. not recorded.
1656	" 11			16 03·0	16 11·5	16 56·8	0·3	P. and S. lost changing paper.
1657	" 11			17 26·1		17 45·2	0·05	Thicken'g at intervals. Doubtful as to being seismic
1658	" 13			12 40·8	12 52·6	13 36·2	0·3	P. and S. not recorded.
1659	" 14			23 15·1			0·05	Doubtful as to being seismic.
1660	" 18			12 28·9		A.C.		
1661	" 21	6 35·7? 6 36·5	6 38·8	6 44·1	6 45·7	8 08·0	2·8	Beginning of P. may not have been recorded. Possibly off Mexican Coast.
1662	" 24			0 13·1		A.C.		
1663	" 24			12 43·3	12 51·5	A.C.	0·2	Thicken'g. P. & S. not recorded.
1664	" 30	3 24·2?	3 28·4?	3 31·0	3 35·4	4 50·8	2·4	2,590 km. P. not well defined. West Indies.

Period of boom 18 seconds. Pillar inclination 1mm. = 0°·50.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1916	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm	
							Less than	
1668	Nov. 3			22 23·6			0·05	
1669	" 10	9 17·8		9 18·3	9 19·1	9 31·1	2·0	Probably in E. Washington State.
1670	" 11		14 01·0	14 04·0	14 07·5	14 46·5	0·3	
1671	" 11		15 47·5	15 51·5	15 55·5	16 15·5	0·3	
1672	" 13			12 31·3	12 38·3	12 52·2	0·1	
1673	" 14			23 25·1			0·05	
1674	" 18	11 57·1?		12 10·0	12 14·9		0·2	
1675	" 18			12 39·2			0·2	May be part of former quake.
1676	" 20			21 47·3	21 53·3		0·1	
1677	" 20	22 58·7?		22 59·7	23 01·7	23 05·7	0·2	
1678	" 21	6 39·4	6 42·9	6 47·4	6 52·3	7 55·3	4·5	2,050 km.
1679	" 24	0 09·3?		0 14·3	0 18·8	0 27·8	0·2	
1680	" 24			13 03·9?	13 06·9	13 14·8?	0·4	
1681	" 25	21 06·6?			21 09·3	21 11·2	0·1	May not be seismic.
1682	" 27	7 17·5?		7 21·0	7 24·5	7 30·9	0·2	
1683	" 30	3 35·0?	3 39·0	3 48·2 3 49·9	3 51·5	4 24·1	1·0	Beginning of P. not defined. L-S; 6000 km.

Boom period 18 seconds. Pillar inclination 1mm. = 0″·54

VERTICAL COMPONENT

Date 1916	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
	h m	h m	h m	h m	h m	μ	
Nov. 21		6 43·2	6 47·0	6 50·3	7 09·0?	* 17	

* True earth movement.

J. V.

ASTRONOMICAL NOTES

EINSTEIN'S NEW THEORY OF GRAVITATION is in part thus elucidated in *Monthly Notices* R.A.S., October, 1916, W. de Sitter.

Since Minkowski the conception of space and time as a four-dimensional continuity has been widely accepted. The ideal put forward by him in his celebrated lecture of 1908, "that space and time each separately should vanish to shadows, and only a union of the two should preserve reality," has, however, only been completely realised by the latest theory of Einstein, the "Allgemeine Relativitätstheorie" of 1915, by which, moreover, gravitation is also incorporated in the union.

The points of space occupied by a given material point at successive times form in the four-dimensional time-space a continuity of one dimension, which is called the *world-line* of the point. Also a light-vibration has its world-line, the projection of which on three-dimensional space is a ray of light. Now what we *observe* are always *intersections* of world-lines. Take, *e.g.*, an observation of an occultation of a star by the moon, and let us imagine, to simplify the argument, that the face of the clock is illuminated by the light of the star. Then the world-line of a certain light-vibration starts from a point on the world-line of the star, it then intersects successively the world-line of a point on the moon's edge, that of the clock's hand, and that of a point on the clock's face. The last two intersections may be said to coincide, so that three world-lines have one point in common. About the course of world-lines between the points of intersection we know nothing, and no observation can ever tell us anything.

The characteristic feature of Einstein's theory is the intimate connection which he has traced between this fundamental tensor and the gravitational field. In all other theories, also in the "old" theory of relativity, gravitation is a "force," like, *e.g.*, electromagnetic forces, which requires its own laws, and these laws have no greater inherent necessity than those of any other natural

phenomenon. In Einstein's new theory, gravitation is of a much more fundamental nature: it becomes almost a property of space. Gravitation certainly differs from all other forces of nature by its generality and its independence of anything else. At a given point in a gravitational field every material point receives the same acceleration whatever its chemical or physical properties may be. Now, if we introduce a new system of co-ordinates which at this point has exactly this acceleration, then the material point subjected to gravitation would be at rest relatively to this new system of co-ordinates, and would thus in this new system be apparently not subjected to gravitation. - By the principle of general relativity there is no essential difference between the two systems of co-ordinates: we have no right to say that either of them is at rest and the other moves. Whether there is at a given point a gravitational field or not thus depends on the choice of the reference-system.

In the old mechanics space is Euclidean, and a material point subjected to no forces describes a straight line with uniform velocity, *i.e.*, its world-line in a Euclidean four-dimensional time-space [the system of reference of the old theory of relativity] is a straight line. In Einstein's theory, if there is gravitation, the four-dimensional time-space is not Euclidean, and the world-line of a point subjected to no other forces than gravitation is a geodetic line. If there is no gravitation, the time-space is Euclidean, and the geodetic line is a straight line as in the old theory. Gravitation is thus, properly speaking, *not* a "force" in the new theory.

In the December number of the *Observatory* Dr. T. J. J. See in reference to the above remarks in part as follows:—

In the *Observatory* for October Professor de Sitter, of Leiden, gives a useful summary of the leading considerations underlying Einstein's Theory of Gravitation; but, whilst he carefully discusses the *analysis* of Einstein's treatment, he so completely passes over all *physical considerations* as actually to convey the impression that gravitation is not a *physical problem*, but only an *analytical one*. In fact, he actually states that under this theory gravitation is not a "force" but "a property of space" (p. 418).

It would be difficult to find a more deceptive piece of reasoning than that here discussed. It is evident that Minkowski, Einstein, and de Sitter have had in view nothing but *analysis*—ignoring the physical universe altogether,—and thus reasoned on a false basis, as has happened more than once in the past history of science.

In this connection the reader might be referred to Whewell's "History of the Inductive Sciences," Vol. I., Chapters 1 and 2, where he shows the cause of the failure of the physical science of the Greeks—namely, that although they were keen observers of nature and reasoned very acutely, *their ideas were not appropriate to the facts*. No mischief is more widespread in modern science than reasoning on false premises, though Aristotle warned us against this practice 2200 years ago, and Newton emphasized the same caution again and again. It is the belief of many experienced investigators that the whole doctrine of relativity rests on a false basis, and will some day be cited as an illustration of foundations laid in quicksand. Dozens of books have appeared on this subject. Thus our problem to-day is not merely to discover truth, but to discover a way out of an ensnaring mesh of errors.

In view of these facts, even the most ætherial pure mathematician ought to realise the impossibility of successfully treating gravitation from the analytical point of view by merely transforming the equations and ignoring the physical conditions which alone enable us to understand these stupendous forces of nature. From a study of these problems running over many years, I venture to think that the chief difficulty consists not in analysis or its transformation—since we know the law of the attractive force,—but in discovering some *physical agency* by which we can consistently explain the enormous forces actually operative in gravitation.

For more than a third of a century I have been at work on the cause of gravitation, and since early in 1914 have been almost incessantly occupied with testing the results and applying them to all known physical phenomena. It will not be out of the way to say that notable progress has been made, with results altogether different from those described by Professor de Sitter as reached by Einstein.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

BOOKS ADDED TO THE LIBRARY

List of Books added to the Library since the last list published (May-June, 1916):

"A Voyage in Space," by H. H. Turner, 1915.

"The Southern Skies," by R. A. Proctor, 1896.

"Seneca, Physical Science in the Time of Nero," translated by J. Clarke, 1910.

"Spinning Tops and Gyroscopic Motion," by H. Crabtree, 1909.

"Astronomy of the Ancients," by Sir G. Cornewall Lewis, 1862.

"Tabulæ Astronomicæ," by Edmund Halley, 1749.

"Historia Cœlestis," by Tycho Brahe, 1692.

"Is Venus Inhabited?" by C. E. Housden, 1915.

"Relativity," by A. W. Conway, D.Sc., F.R.S., 1915.

"Sir William Huggins and Spectroscopic Astronomy," by E. W. Maunder, 1913.

"Stars of the Southern Skies," by M. A. Orr, 1915.

"Meteorites," by O. C. Farrington, Ph.D., 1915.

"The Universe as Pictured in Milton's 'Paradise Lost'," by W. F. Warren, 1915.

"The Earth's Beginning," by Sir Robert Ball, 1909.

"The Origin of the Earth," by Thos. Chrowder Chamberlin, 1916.

"A Letter Concerning the Rise and Progress of Astronomy Among the Antients," by E. Costard, 1746.

"Life of James Ferguson, F.R.S.," by E. Henderson, LL.D., 1867.

"Unfinished Worlds," by S. H. Parkes, F.R.A.S., F.L.S., 1888.

"Practical Navigation and Nautical Astronomy," by J. W. Norie, 1894.

"The Cities of the Sun," by Geo. W. Warder, 1901.

"An Explanation of the Gnomonic Projection of the Sphere," by A. de Morgan, 1836.

"Histoire de l'Astronomie," 5 vols., by M. Bailly, 1779-87.

"Fundamenta Astronomiæ," by J. Bradley, 1818.

GRAVITATION

Among the interesting publications which come to our Society's Library from sister societies is the *Journal and Transactions* of the Leeds Astronomical Society. It is published by Wesley & Son, 28 Essex St., Strand, London, the price being 2 sh. The volume for 1915 is number 23 in the series. In it is a paper on "Gravitation" by Professor C. T. Whitmell, M.A., F.R.A.S., who is editor of the publication, and some extracts from this were printed in the "Astronomical Notes" of this JOURNAL for October last. Professor Whitmell writes as follows:

In Vol. X., pp. 463-4, you have done me the honor of quoting a few passages from my 'popular' paper on "Gravitation," published in Vol. XXIII., of the Leeds Astronomical Society's *Journal*, 1915. On pp. 521-2 you publish some criticisms by Dr. Klotz, who, I assume, has not seen the original paper. Quite early in the paper I give the equation,

$$F = G M_1 M_2 / d^2$$

and state that the attraction between two particles, whose masses are M_1, M_2, at a distance d, is equal to the product of the masses, divided by their distance squared, and multiplied by a certain factor G, known as the constant of gravitation.

Now, obviously, when the C. G. S. units, of mass and distance are taken, G is numerically equal to F in dynes and this

is what is implied by the statement (quoted p. 463) that G represents in dynes the attraction under such conditions. Of course, as Dr. Klotz points out, F and G (though numerically equal) are not of the same dimensions, but the subject of dimensions seems hardly suitable for a 'popular' paper. However, I may add a note on this point in a future Leeds *Journal*.

Dr. Klotz also states that I confuse mass and weight, using the latter when I mean the former. But he gives no actual example of this, and I cannot find one.

What I have done is repeatedly to express the attraction between two bodies in terms of a weight, that is of the force with which the earth attracts, say, a mass of one grain, or of one pound, this force being, of course, the weight of such mass. This I hold to be correct, and I purposely used this statical measure of force, because it is the one with which everybody is familiar. For simplicity the variation with latitude is neglected for ordinary examples.

What I shall really be grateful for is a careful recalculation of the numerical results in my original paper, so that I might know if there are any errors in them.

HYDE PARK, LEEDS, ENGLAND,
November 28, 1916.

THE AURORA OF SEPTEMBER 30, 1916, 8 TO 10 P.M.

Dr. A. A. Hibner, M.A., of Welland, sends a report on the above aurora, as follows :—

I was stopping at a farm house about ten miles south of Welland on that evening. The man with whom I was staying called me out to see the wonderful sight.

I never saw such a magnificent display. Great bars of light or streamers would shoot up, reaching almost to the zenith, then large cloud-like appearances came up that looked like a leviathan sailing upon a sea of light. They would move back and forth about 30° above the northern horizon and disappear suddenly for a short time, after which great bars would shoot up

again. Then it would change and radiate from some one point in a fan-like shape and cover the northern sky.

I have not been able to find any satisfactory explanation of that phenomenon and am gathering material on that subject.

One thing is certain,—that it is not caused by the sun, or material falling into the sun, as some suppose. At this season of the year there is no sunshine in the northern polar regions. Nor can it be reflected light or due to aberration. To my mind it is purely an electrical phenomenon, but the causes of which are yet unknown to science.

The changes from bars to streamers, or clouds, etc., may be due to the atmospheric conditions which would change the electric currents.

DISTANCE OF BARNARD'S "RUNAWAY" STAR.

Ever since the discovery by Barnard last June of the rapidly moving star in Ophiuchus (see this JOURNAL, vol. x., p. 343), it has been the subject of considerable investigation. Its velocity towards us has been measured at the Lick, Mt. Wilson and Lowell Observatories and the values obtained are 128, 91 and 40 km. per sec., respectively. In Harvard *Bulletins*, 616, 617, preliminary values of the star's parallax are given. At Allegheny, measurements yield 0″.5 ; and from micrometric measures made by Barnard, Russell deduces a value 0″.70. Either of these values would place the star as nearest to us after Alpha Centauri. The latter's parallax is 0″.76 and distance 4.3 light years; the parallax 0.70 for Barnard's star would give it a distance 4.7 light years. Its real brightness is computed to be one three-thousandth that of the sun, making it the faintest star so far known.

DEATH OF DR. OSKAR BACKLUND.

In April, 1916, Dr. Oskar Backlund, who had been director of the Imperial Observatory at Pulkova, Russia, since 1893, and who was one of the world's most eminent astronomers, was elected

an Honorary Fellow of the Royal Astronomical Society of Canada. We regret to say that he died on August 29, in his 75th year. There were five others elected at the same time as Backlund, namely, Lowell (who has also died) Dyson, Baillaud, Schlesinger and Turner.

THE PASSING OF PERCIVAL LOWELL.

In our present issue appears a sketch, all too brief, of the life of Percival Lowell, by Prof. Frank W. Very, well known for his work on solar radiation and on other subjects.

Dr. Lowell visited Toronto in the spring of 1916. Learning that he would lecture before the Chicago Academy of Sciences during April, an urgent invitation was sent to him to come on to Toronto and favor in a similar way the Royal Astronomical Society of Canada. The lecture was given on the evening of April 27, the subject being "The Genesis of Planets." On this occasion it was announced that Dr. Lowell and five others had been elected Honorary Fellows of the Society. The lecture was published in the JOURNAL for July-August. It was accompanied by some beautiful illustrations, which were either from Dr. Lowell's own hand or from photographs taken at the Lowell Observatory.

During his stay in Toronto he attended a luncheon of the local Harvard Club, one of the leading spirits of which is Benjamin Apthorp Gould, a worthy son of the distinguished founder of the *Astronomical Journal*. He was also the guest of honor at a small dinner at the University of Toronto Faculty Union, attended by a number of his astronomical admirers. Those who were present will long remember his witty and kindly remarks and especially his clear and reasonable explanation why some observers failed to see the Martian markings while others recognized them without difficulty.

In the months of May and June the present writer spent some weeks at Cambridge, Mass., and he had occasion to meet Dr. Lowell a number of times, indeed many courteous attentions were received from him. In answer to inquiries, it was learned that

Dr. Lowell was not in the best of health. His digestion was not satisfactory and he was troubled with insomnia. However, he felt well enough in September to undertake a series of lectures in the north-west and western states. On this trip, as always, he was accompanied by Mrs. Lowell, who gave him whatever attention that devotion and thoughtfulness could suggest. After the lecture at Berkeley, Cal., they went to Arizona. On the evening of Saturday, November 11, Dr. Lowell appeared in good health, but next morning he was stricken with apoplexy and he died at night without recovering consciousness.

To those who met Dr. Lowell it was evident that, while he had a wide knowledge of political and financial matters, science was the ruling passion of his life, and to become distinguished in it was his greatest ambition. To attain this laudable object the Lowell Observatory was founded over twenty years ago and has been maintained ever since purely for research. Much work of a high order of excellence has been produced by its director and his capable assistants. This institution will be continued under provision made by Dr. Lowell and it will ever remain a noble monument to his memory.

C. A. C.